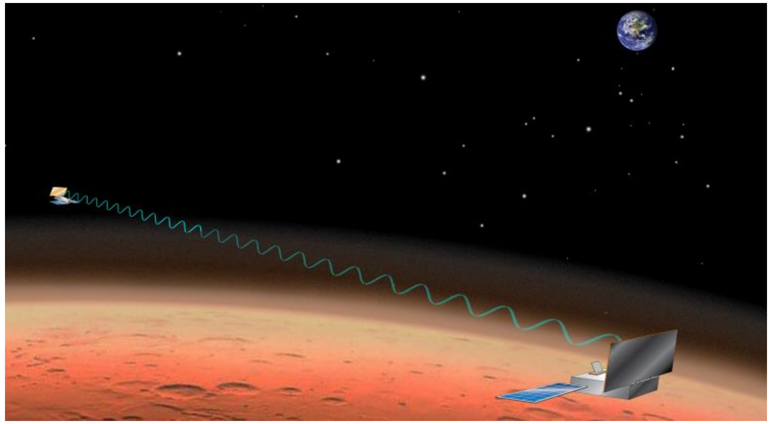

AGU FALL MEETING
New Orleans
11-15 Dec. 2017 What will *you* discover?

Small Spacecraft Constellation Concept for Mars Atmospheric Radio Occultations

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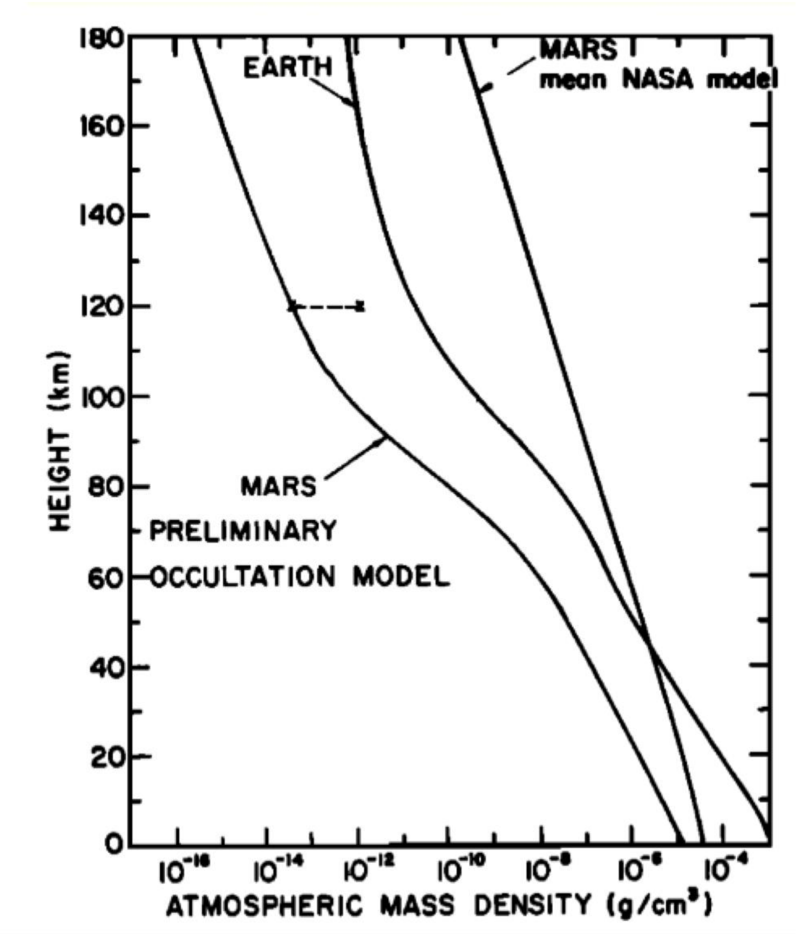
Government sponsorship acknowledged.

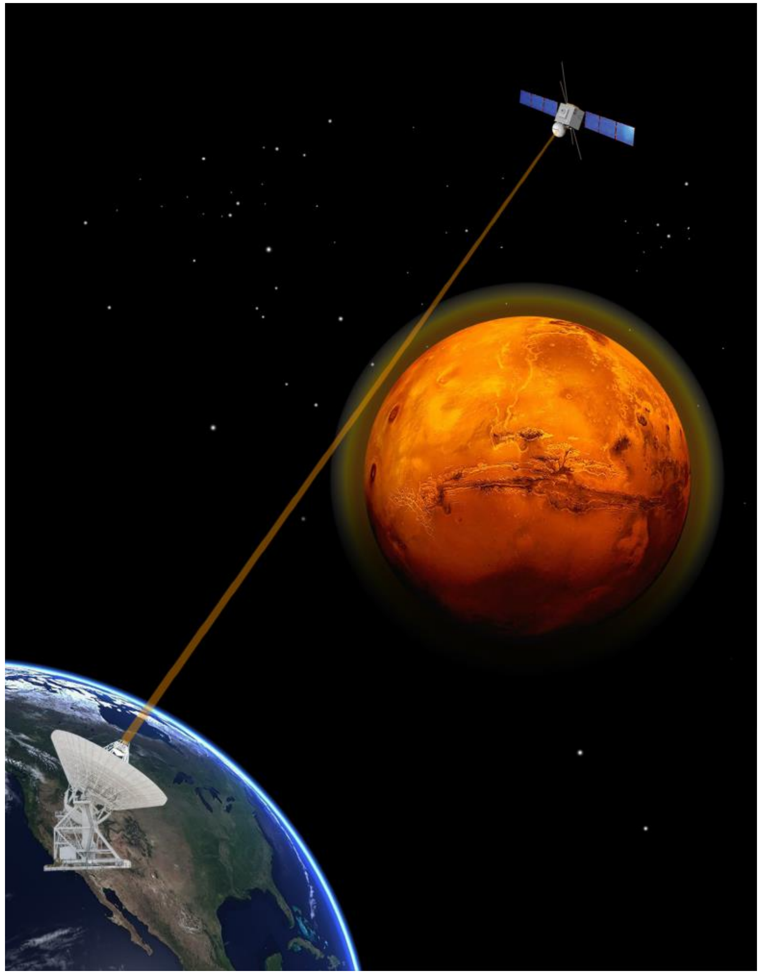
Atmospheric Radio Occultations

- Temperature-pressure profiles
- Ionospheric density and structure
- First results in 1965

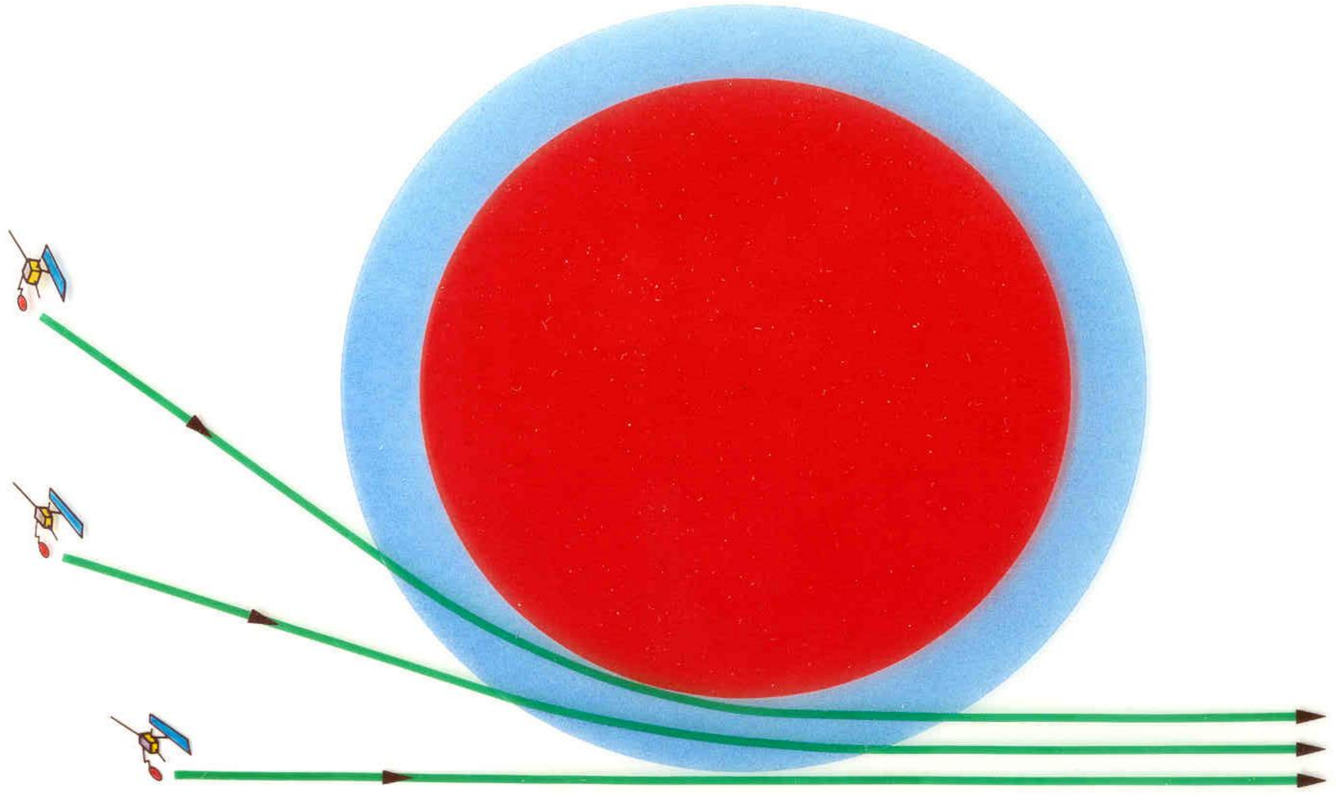
- Technique later applied to occultations of planetary rings, plasma torus, and solar corona



Kliore et al, 1965

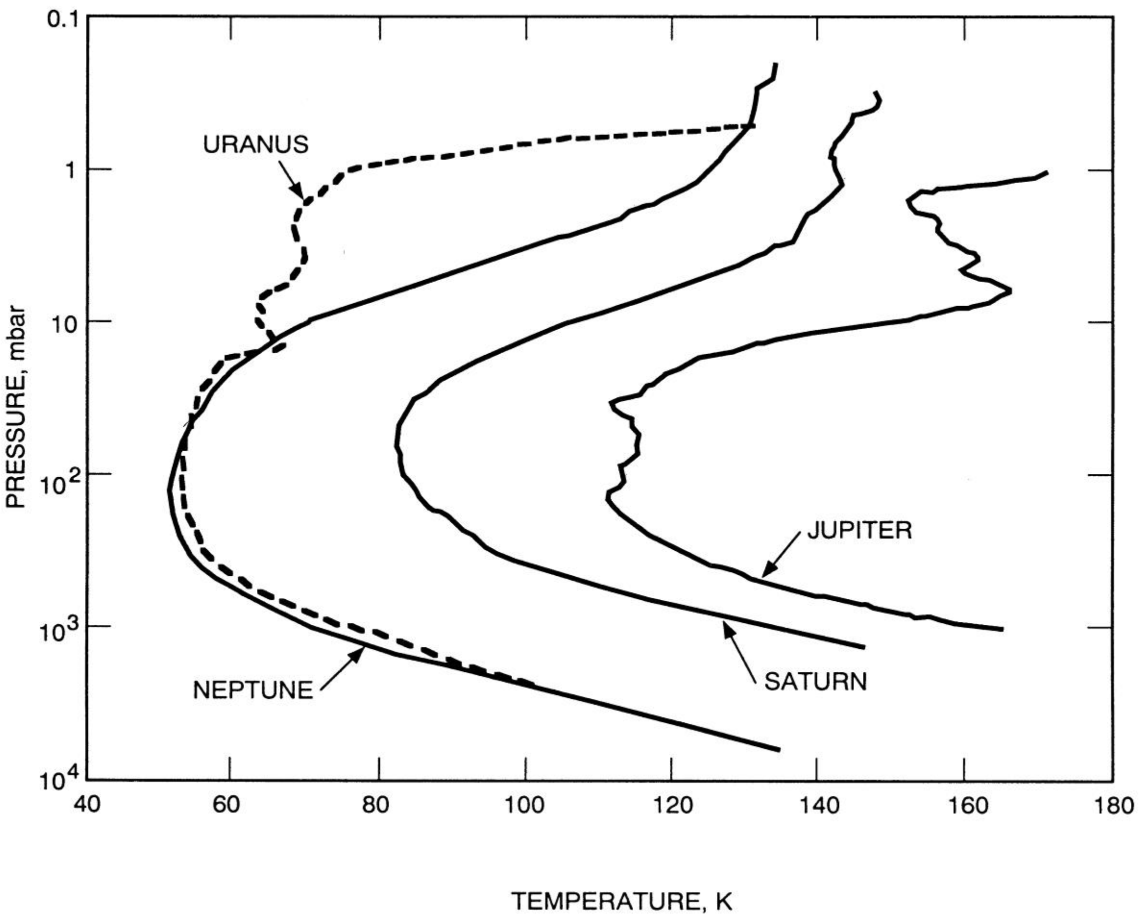


Phase Change → Path Length → Refractive Angle → Refractivity → Number Density → Column Pressure → Temperature Profiles

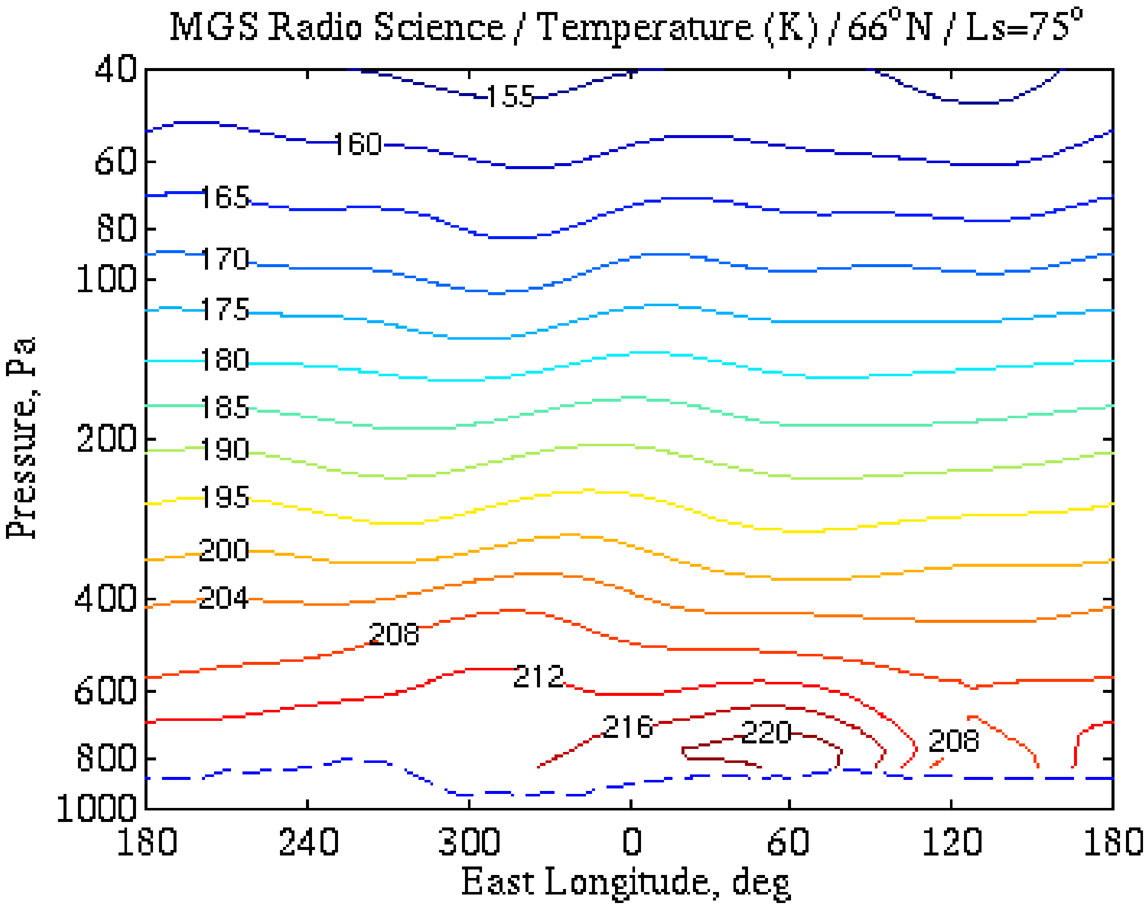


Source: M. Patzold

Flybys at Outer Planets vs. a Decade in Mars Orbit

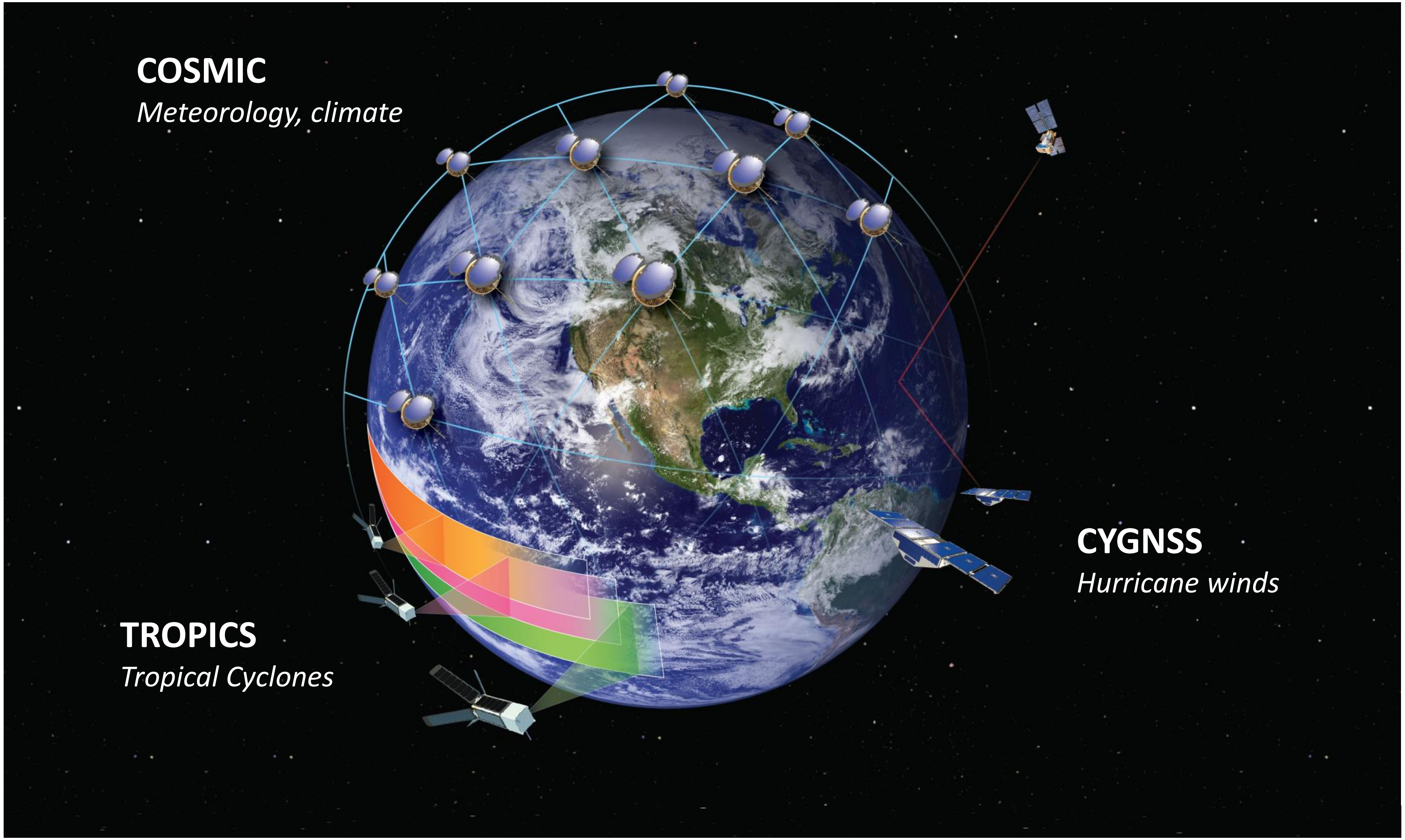


Temperature profiles for the giant planets derived from radio occultation data acquired with the Voyager spacecraft (from Lindal, 1992)



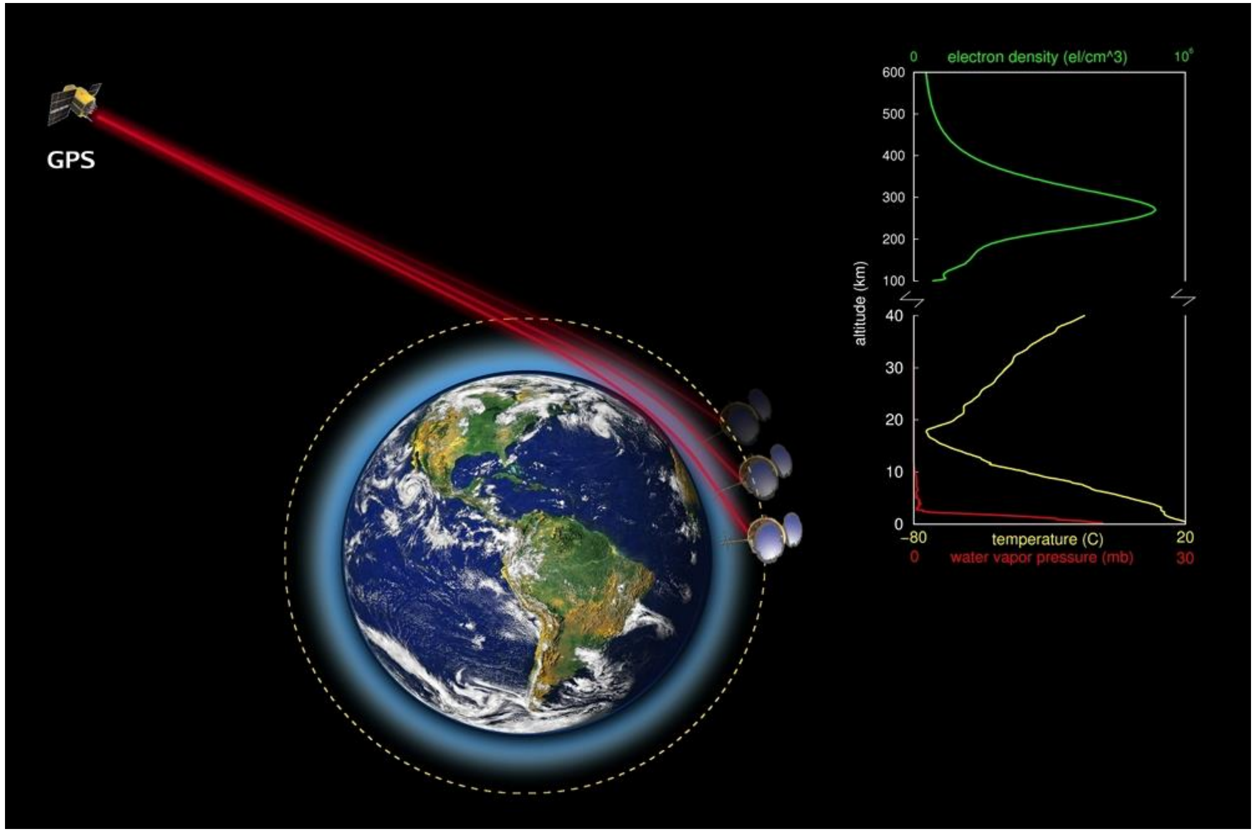
Source: D. Hinson

Earth Atmospheric Occultations via Constellations



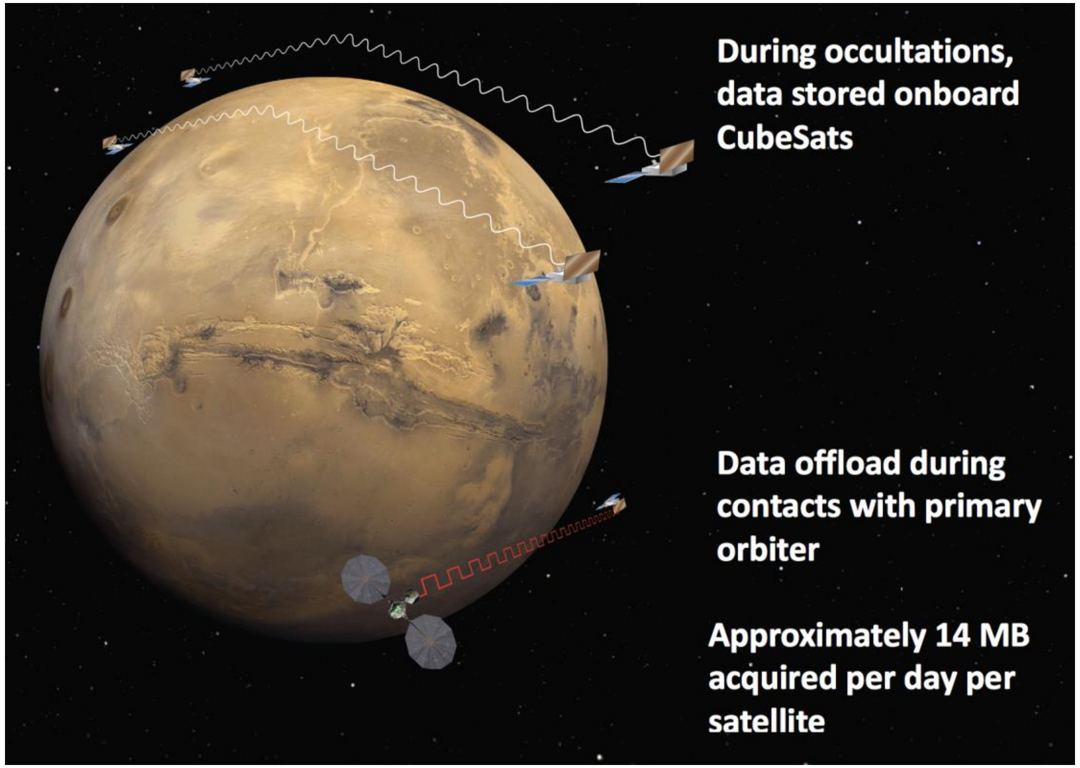
Earth Atmospheric Occultations Example Results

- Anthes et al., 2008, COSMIC/FORMOSAT-3
- 6 microsatellites launched into 512-km orbit providing 1500 RO daily
- Global 3-D coverage: 40 km to surface
- 70% - 90% of RO reach to ~1 km of surface
- Vertical resolution: ~100 m in lower troposphere
- Independent height, pressure, and temperature data
- High accuracy: averaged profiles to < 0.1 K



From *Spacecraft-to-DSN* to *Spacecraft-to-Spacecraft*

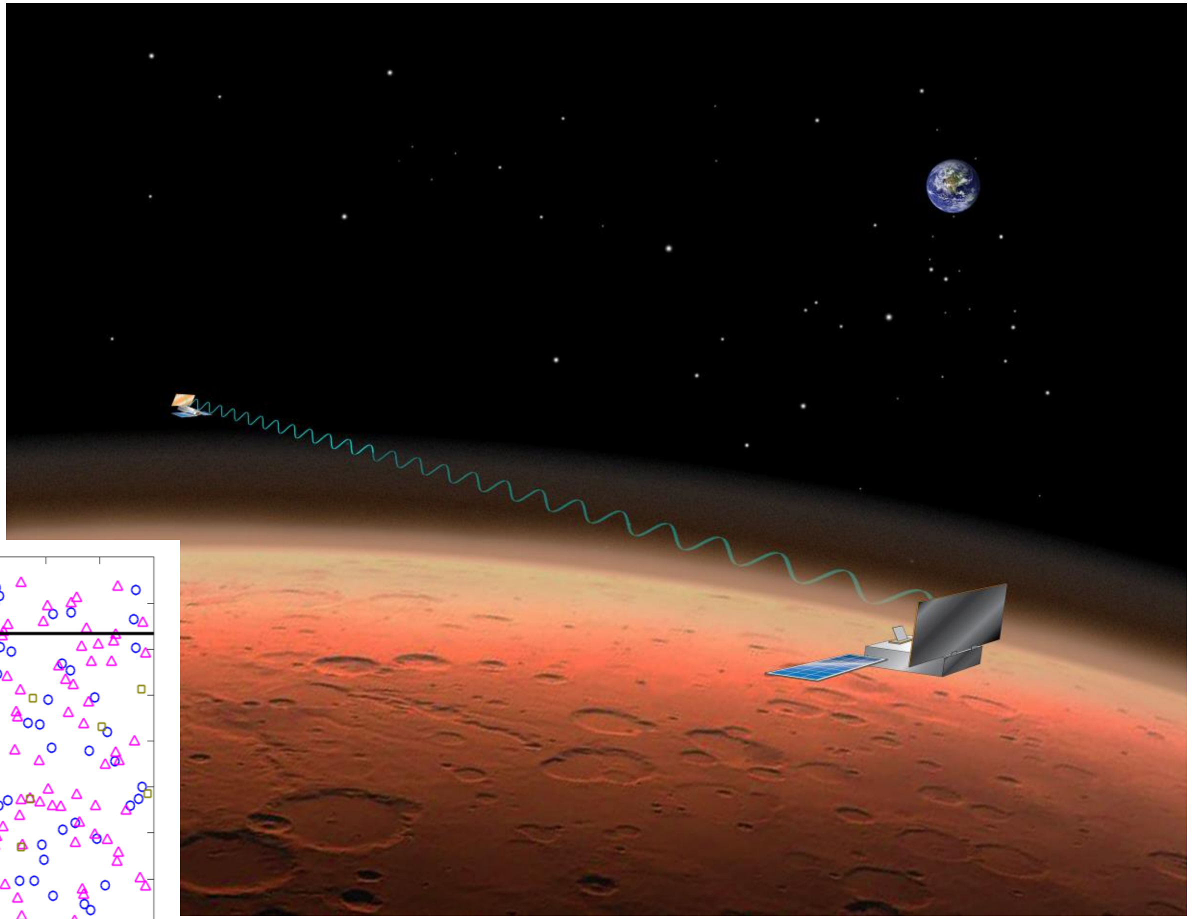
- 5 decades of planetary spacecraft links to Earth
  - *Reversed DSN-to-spacecraft for NH at Pluto*
- Earth science community advanced technique via GPS satellites transmitting to science spacecraft
- Carry *crosslink* concepts to planetary atmospheres for tremendous advantages
- Science motivation & assist human missions (✔)
- Need mission design & navigation (✔)
- Need radio instrumentation (✔)
- Need small spacecraft platform (✔)
- Need a demo of concept (✔)
- Ready for science mission implementation



Pre-Decisional Information -- For Planning and Discussion Purposes Only

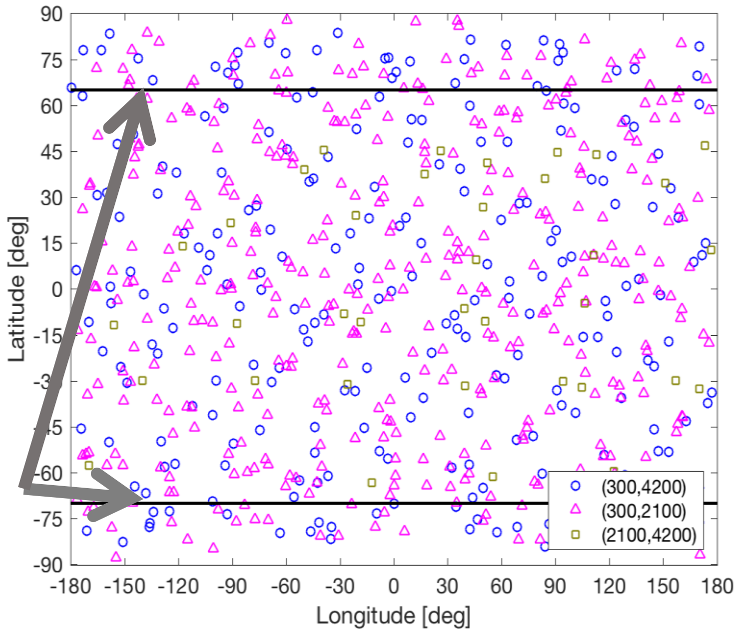
Advantages of Crosslink Radio Occultation

- Improve temporal & spatial resolution
- Rapid global coverage with diurnal, seasonal, annual repeatability
- High vertical resolution of T-P profiles
- Not obscured by dust & profiles reach surface
- Possibly higher SNR



- Three CubeSats at 3 altitudes
- Pairwise occultation locations
- One week acquisition time

- Compare to single polar orbiter one week spacecraft-to-DSN covering polar regions only



Pre-Decisional Information -- For Planning and Discussion Purposes Only

MEPAG Goal II: Understand Processes & History of Climate

Objectives	Sub-objectives
A. Characterize the state of the present climate of Mars' atmosphere and surrounding plasma environment, and the underlying processes, under the current orbital configuration.	**A1.** Constrain the processes that control the present distributions of dust, water, and carbon dioxide in the lower atmosphere, at daily, seasonal and multi-annual timescales.

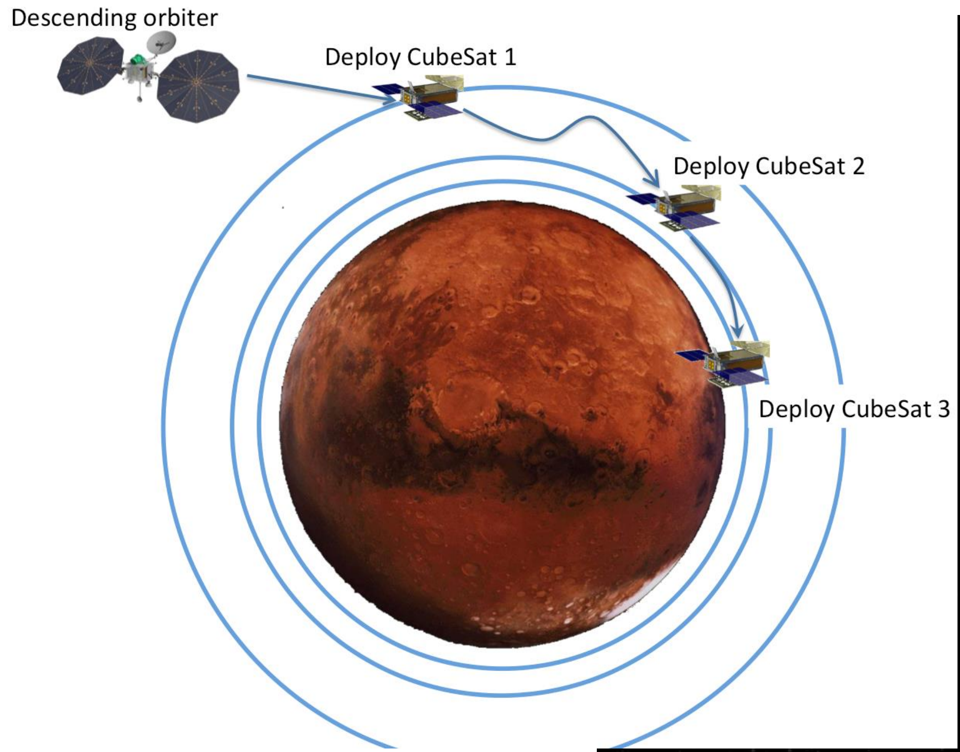
Investigation A1.1: Measure the state and variability of the lower atmosphere from turbulent scales to global scales (High Priority).

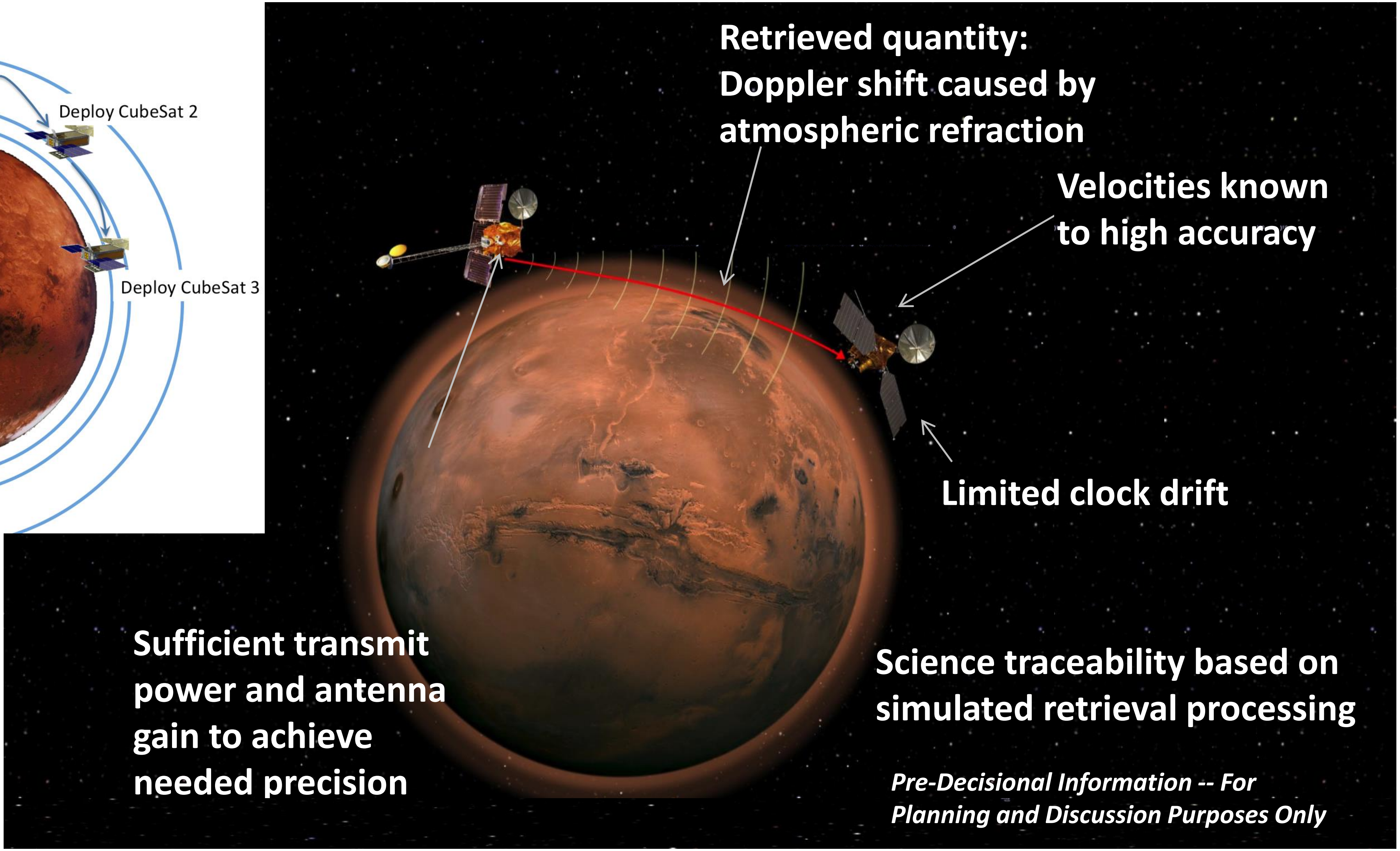
MEPAG Goal IV: Prepare for Human Exploration

B. Obtain knowledge of Mars sufficient to design and implement a human mission **to the Martian surface** with acceptable cost, risk, and performance.	**B1.** Determine the aspects of the atmospheric state that affect Entry, Descent, & Landing (EDL) design, or atmospheric electricity that may pose a risk to ascent vehicles, ground systems, and human explorers.

Investigation B1.2: Monitor surface pressure and near surface meteorology over various temporal scales (diurnal, seasonal, annual), and if possible in more than one locale (High Priority).

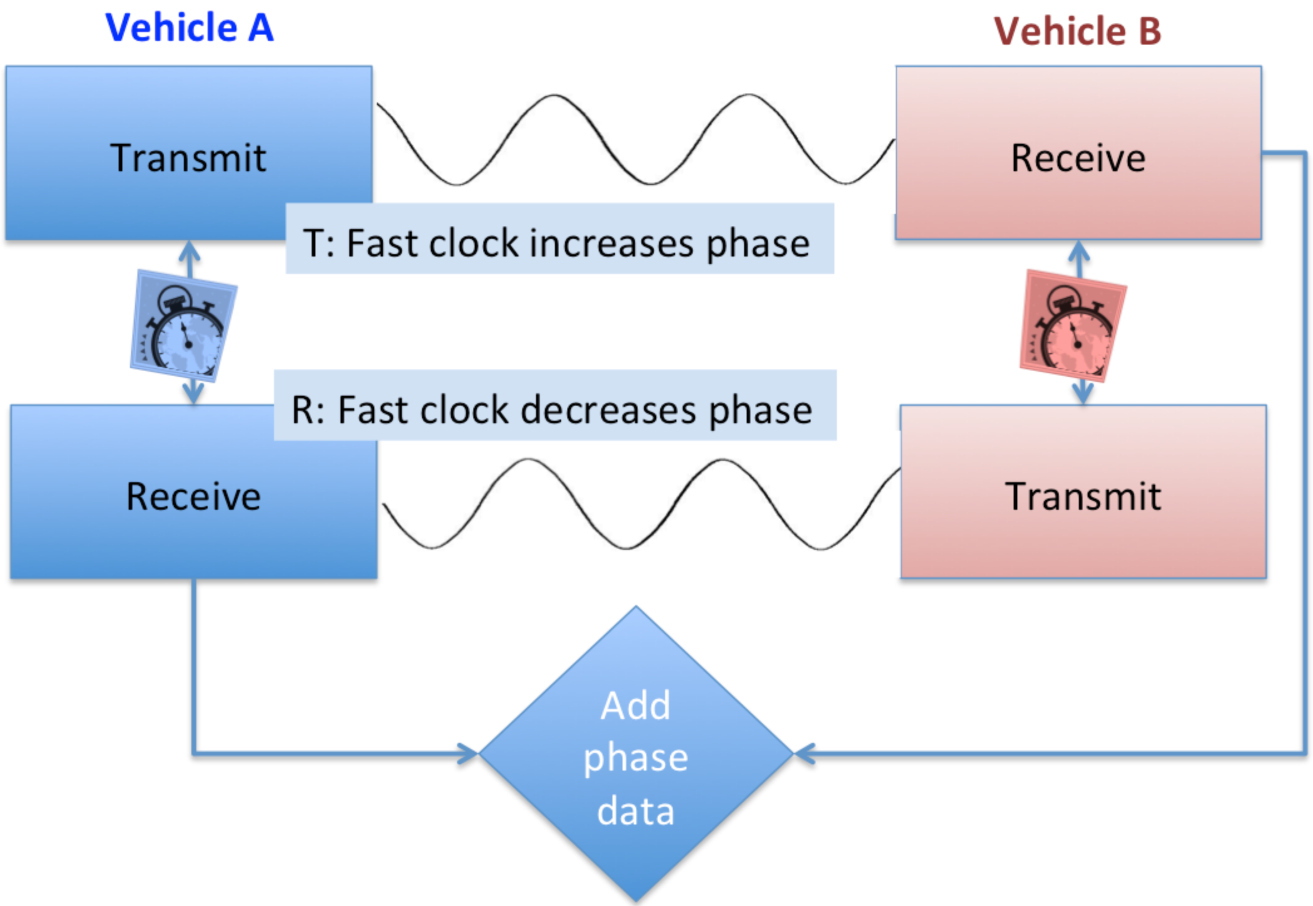
Measurement Physics Drives the Design Concept



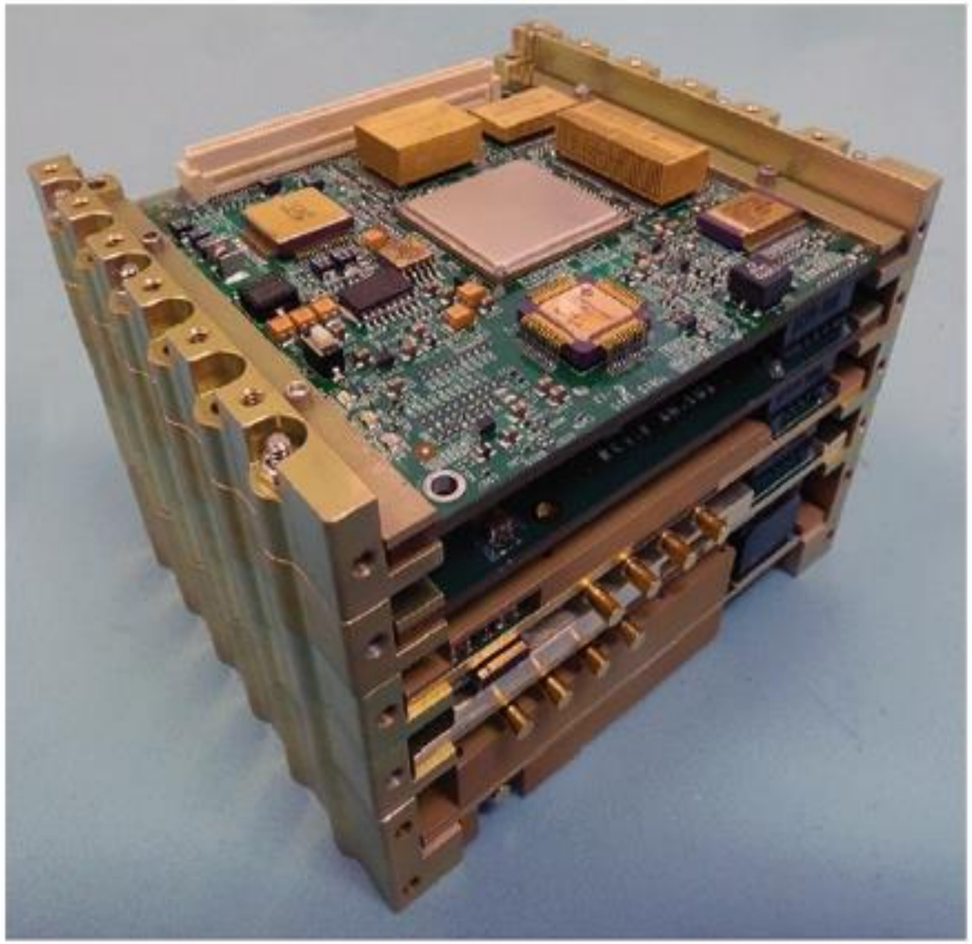


- **Deploy during descent of delivery orbiter**
- **Differential precession of orbit planes achieves desired variety of orbits**
- **Candidate altitudes: 4200, 2100, & 300 km**

Iris Radio with Dual-One Way Range Rate



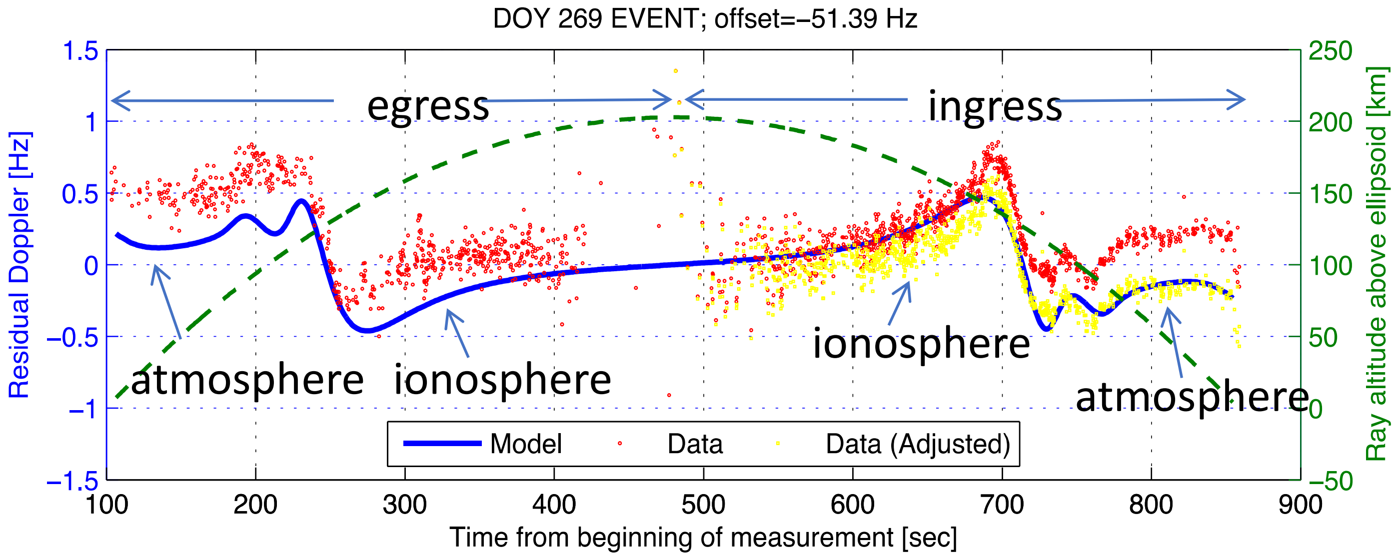
Summing phase data in post-processing reduces clock errors



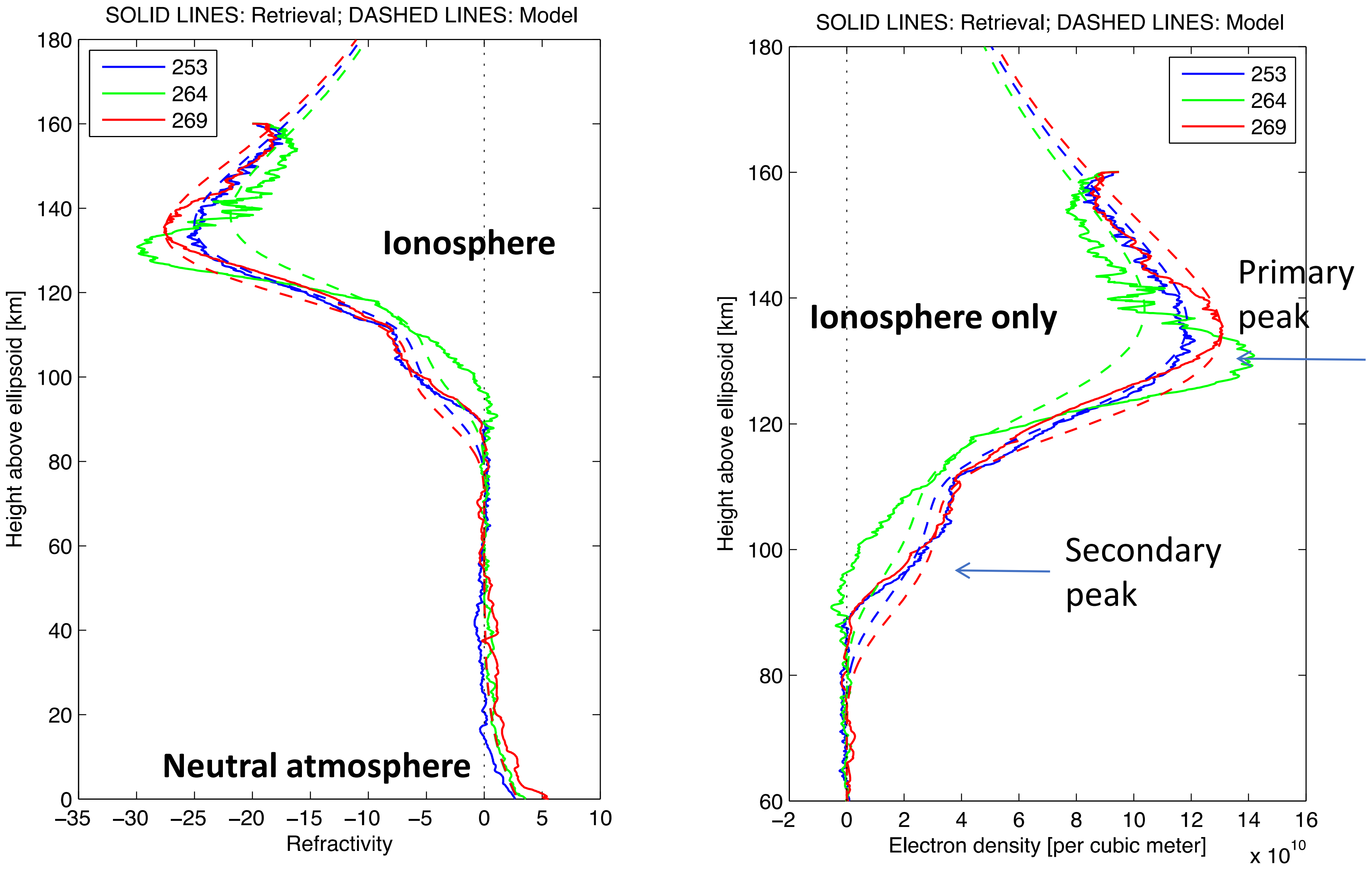
Simultaneous X-band transmit/receive capability
Navigation requirements achieved with crosslink measurements above atmosphere and links to orbiter

Demonstration: UHF Link from Odyssey to MRO

- **Found geometries where orbiters communicating with rover on surface were in line-of-sight for a crosslink (λ ~75 cm); made possible due to flexible design of the Electra software-defined radio.**

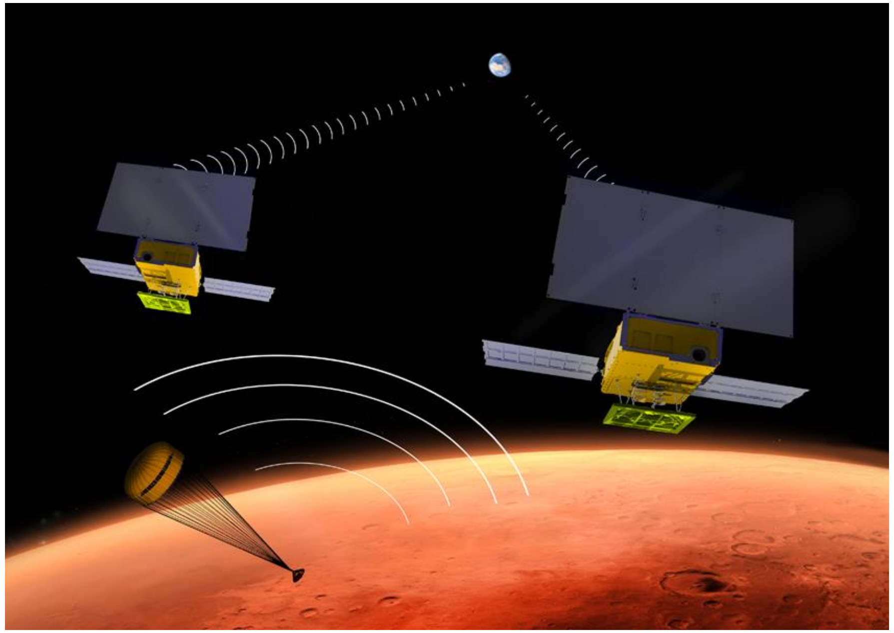


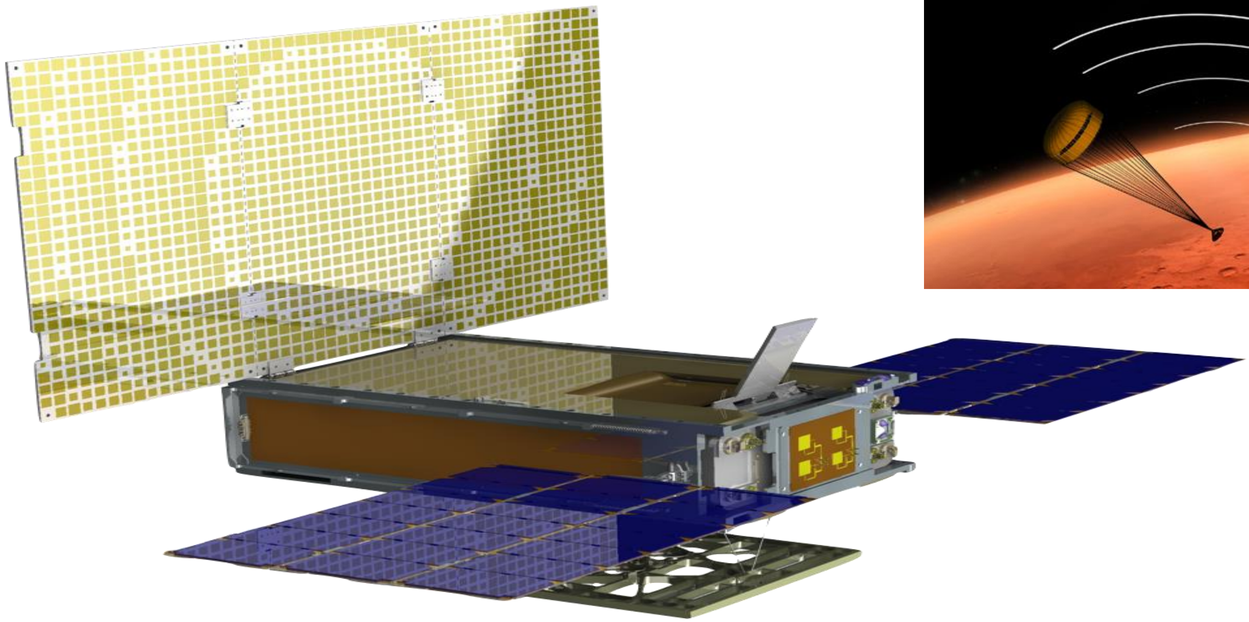
Ionospheric Retrievals from UHF Radio



Start with the *Mars Cube One* (MarCO) Design

- 6U, soon to be first planetary CubeSat
- Make radio system the science instrument
- Cost savings, lower risk
- MarCO's X-band reflect-array (relay of 8 kbps) replaced by patch antenna
- Other simplifications





Source: Asmar, S.W., "Mars Relay CubeSat," NASA Tech Briefs Magazine, September 2015.